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Professional Profile of
Dr J(Bob) Balaram

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Conspectus:

Balaram, mechanical engineering graduate of IIT, Madras (1980), was awarded Ph.D in 1985 from the American University. Dr Balaram joined JPL (NASA) and was a lead/principal investigator of many Mars exploration missions. Ingenuity helicopter (Hi) of 1.8 Kgs was his brain child. The gestation period was over two decades from conceptualization to the tiny robot (taking the functional form in JPL,Caltech) flying on Mars. It is the first powered flight on another planet in solar system. The NASA's sanction was as a technology demonstration project. Hi's performance in first five flights (IF1 to IF5) excelled and exceeded the expectations of experts. It is a testimony for robustness of hardware and software modules. NASA extended its mission under the head operations demonstration. The unperturbed health and functionalability in tact after tenth flight were amazing. This pushed its active participation in Mr. Perseverance Rover Sample Caching Systemscience mission.Ingenuity, non-life robotic system, came into being (physical existence) because of a small but passionate team of NASA bagging discoveries and inventions aimed at welfareof progeny of humankind.

Born on September 22, 1952

Tamil Nādu (India)

Chief engineer
Ingenuity helicopter,
JPL, NASA, USA

13th Flight
https://youtu.be/bLuZpk9K20Q

Inspiration for J(Bob) Balaram in Space missions

- ➔ Balaram, a nine year old child,“ gobbled up" every thing that broadcated on the radio about the Apollo moon mission
- ➔ Glossy booklets from NASA entranced young Bob
  - ➔ This was a response to Bob uncle’s request to U.S. Consulate for information about NASA and space exploration
  - ! Long long before the internet, the U.S. had good outreach
- ➔ From then on Balaram was fascinated and piqued by the cosmic world and space

	Inspiration stage (Is) to Ingenuity First flight (Iff) Timeline for **Dr J (Bob) Balaram**
1990	✓ Prof IlanKroo of Stanford univ spoke about a ‘mesicopter — a miniature airborne vehicle for applicationsonEarth‘

	✓ NASA funded the project under"Innovative Advanced Concepts" ✓ **From to-do to done** ✓ A seed of thought was sown in the Dr Balaram's mind to fly an appropriate small vehicle on MARS
Proposal submitted	To NASA Research Announcement It is in joint collaboration with StanfordUniv & Recruited AeroVironment, a small company in Simi Valley, California
	✓ The proposal got favorable reviews - But it was not selected for funding at that time, ! It did yield a blade-rotor test under Mars conditions at JPL
15years	! Idea "sat on a shelf" for 15 years

! **Revival**
! Charles Elachi, then the director of JPL, attended a conference ☞ University of Pennsylvania presented about the use of drones and helicopters
? Dr Elachi, asked whether something like that could be used on Mars
o A colleague of Balaram's mentioned Bob's previous work in that area of research
☞ Elachi asked Dr Balaram to write a new one for the competitive call for Mars 2020 investigation payloads
! **Second Hurdle**
- Helicopter idea was not selected as an instrument + Funded for technology development and risk reduction

Start of project	
☞ Mimi Aung became Mars Helicopter project manager ☞ Team worked on risk reduction	
! Funding	
✓ NASA decided to fund the helicopter for flight as a technology demonstration	
! Landing on MARS	
2021February 18	Ingenuity arrived on Mars
2021April 19	It took its first 39-second maiden flight

F1 to F5 : successful technology demonstration flights
F6 to F9: successful Operation demonstration flights
F10 to F13: successful exploration experimental learning (Eel) flights

Off the Earth, for the Earth, and Beyond

Appreciation of Ingenuity helicoptor (Hi!)

MiMi Aung (Burmese-American) is a project manager at NASA's Jet Propulsion Laboratory (JPL); lead engineer on the Mars Helicopter Ingenuity said

- “This morning our dream came true.”
- “It is an incredible moment”
- This flight (Hi) (extraterrestrial aircraft) is compared to Wright brothers' airplane which was the first flight in 1903 at Kitty Hawk on Mother earth
- Beginning of the "pioneer era" of aviation on MARS, the first planet other than earth in our solar system

Appreciation of **Dr J(Bob) Balaram**

- Dr Bob is the inventor of our Mars Helicopter
- It is his innovated vision to its fruition (as a chief engineer) through all phases of design, development, fabrication and test

Open heart with Ingenuity helicoptor (Hi!)

Interviewer: Did people thought that the idea of Mars ingenuity was crazy
Balaram: “Everyone. All the time."

- ✓ A postage-sized piece of fabric that covered one of the wings of the Wright brothers' first aircraftwasattached to a cable under the solar panel of Ingenuity. Now the cloth is on MARS with Hi and its mother perseverance afer a travel for over six months from Earth

- ✓ Ingenuity helpsscientists on Earth in three tasks viz. - reach, range and resolution
  - to look at hard-to-reach places like steep cliff walls, caverns or other geological strucures on Mars
- ✓ Helicoptors have a larger range compared to rovers, but with different specific purposes designed for

- ✓ Bob opined before landing that these helicoptors basically opens up a whole new dimension of exploring Mars
- ✓ Now that Hi excelled its performance both in technology and operations demonstration phases, higher versions with new feaatures open new doors to aviation scientific exploration along with roverson MARS and other planets (Moons) in coming decades.

- ✓ More than ten engineers of Indian origin are involved in the mission,

Expertise of Dr J(Bob) Balaram

- Precision landing methods for Mars
- Advanced simulation techniques for planetary a high-fidelity EDL (Entry, Descent and Landing)
  - Adapted& used in Curiosity and Perseverance rover missions
- Machine vision for rover hazard detection, improved methods for rover position determination, rover system re-configuration, and software system architectures for rover development
- Vision-based sensing to achieve automation of servicing operations
- Module change-out and assembly
- Remote Surface Inspection for the Space Station in the area of real-time, vision-based flaw detection of damage caused to the Space Station over its lifetime in orbit
- Combined EDL-Mobility Analysis Trade Study Tool (CEMAT)
- SHERPA System
- Telerobot
  - Technology development Testbed for Mars Rovers, planetary balloon aerobot systems

Lead of team

- EDL simulator adapted for use in the Mars Science Laboratory mission.
- Co-developed a simulator used for planetary rover simulation
- machine intelligence on the JPL Telerobot Testbed
- responsible for coordinating multiple robotic manipulators

Principal investigator	Beyond Monte-Carlo - Statistical Verification and Validation of Space Systems for entry, descent and landing	DRDF, JPL.
Principal Investigator May 2004 - July 2008	Sherpa System Mars Base Technology Program	NRA, JPL
Task Lead September 2000-Present	EDL Modeling & Simulation, Mars Technology Development Program,	JPL

	Awards to Dr J(Bob) Balaram
Two	NASA Awards
Eight	New Technology awards
	NASA Group Achievement Award It been adopted for use by the upcoming Mars Science Laboratory mission

Earlier flight projects of **Dr J(Bob) Balaram**

2011	Mars Science Laboratory
2007	Phoenix Mars Lander

Academic profile of Dr J(Bob) Balaram

1975-80	B.Tech	Mechanical Engineer	IIT, Madras, India
1982	MS	Computer and System Engineering	America's Rensselaer Polytechnic Institute
	Thesis	Analysis of Boiling Water Nuclear Reactor Stability Margins	
1985	Ph.D	Computer and System Engineering	America's Rensselaer Polytechnic Institute
	Thesis	Suboptimal Control of Nonlinear Systems	

Rearch papers ofDr J(Bob) Balaram

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Small steps for human scientist	**Giant leaps in science (and for humankind)**
https://youtu.be/oYE3knI__5M	Mars Helicopter Ingenuity's 4K images from 13th flight and full video footage, Sep 11, 2021, 32,565 views by 16th Sep, 2021

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